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Docket Number:	P-2202-USP

PROVISIONAL APPLICATION FOR PATENT COVER SHEET (Small Entity)

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)/APPLICANT(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
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☐ *Additional inventors are being named on page 2 attached hereto*

TITLE OF THE INVENTION (280 characters max)

APPARATUS AND METHODS FOR MEDICAL DIAGNOSTIC AND FOR MEDICAL GUIDED INTERVENTIONS USING MULTIPLE IMAGING SYSTEMS

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒	Specification	*Number of Pages*	37	☐	Small Entity Statement
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METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Respectfully submitted,

SIGNATURE ______ Date 03/31/1999

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P19SMALL/REV04

APPARATUS AND METHODS FOR MEDICAL DIAGNOSTIC AND FOR MEDICAL GUIDED INTERVENTIONS USING MULTIPLE IMAGING SYSTEMS

FIELD OF THE INVENTION

The present invention relates to apparatus for performing medical diagnosis, medical interventions or therapy planning and medical image guided interventions when two or more medical imaging systems (such as an ultrasound, CT, MRI, X-Ray) are available for imaging a target in a body or body volume. Particularly, the present invention is related to apparatus for performing medical interventions, when employing medical imaging systems for viewing the target during the intervention.

BACKGROUND OF THE INVENTION

During recent years fusing images from different medical imaging systems in order to receive a better diagnostic has become widely used. Additionally, the cooperative operation of several medical scanning devices can reduce the amount of radiation at which it a patient is subjected during diagnosis, therapy planning and medical procedures and interventions. While these facts have been already recognized, the realization of such cooperative operation was until now restricted to medical imaging devices having a common mechanical platform.

SUMMARY OF THE INVENTION

During diagnosis it is sometimes necessary or helpful to operate several medical imaging devices simultaneously or sequentially, upon necessity and compatibility between the devices, in order to indicate the condition of the patient and/or designate a target in a body or body volume. For example the same target can be viewed by ultrasound and by some other medical imaging device such as a CT. MRI or X-Ray. The current invention enables the accurate measuring of the relative position between the different imaging detectors by means of attaching position measuring components at known positions from each medical scanning head, canceling the necessity to have a mechanical connection between the different medical scanning devices. Measuring the relative position between the medical scanning detectors enables the calculation of the relative position between the scanning planes/volumes. The term position measuring components will define any of the following group: transmitter or receiver or reflector or transceiver or optical indicia or any combination of the above, suitable to be part of a position measuring system. This position measuring system may be magnetic, acoustic or optic.

The systems and methods of the present invention facilitate the combination of the advantages of a number of medical imaging devices to perform various medical diagnostic, therapy planning and intervention tasks more safely and efficiently than those of the conventional systems.

Additionally, the present invention enables placing one imaging device, for example a CT or an X-Ray over the desired target to be viewed with greater precision, therefore reducing the necessary number of images to be taken by that imaging device.

Additionally, it enables to view a target with one medical imaging device and guide a medical intervention tool or a medical therapeutic tool or insert a medical device when using a second medical imaging device. This can be particularly useful when employing image guided medical intervention systems such as those introduced by the assignees in commonly assigned U.S. Patent No. 5,647,373, entitled: Articulated Needle Guide For Ultrasound Imaging And Method Of Using Same, and patent applications, PCT/IL96/00050 (WO 97/03609), entitled: Free-Hand Aiming Of A Needle Guide; PCT/IL98/00578, entitled: System And Method For Guiding The Movements Of A Device To A Target Particularly For Medical Applications; and PCT/IL98/00631, entitled: Calibration Method And Apparatus For Calibrating Position Sensors On Scanning Transducers, all four of these documents incorporated by reference in their entirety herein.

Additionally, the present invention enables viewing of a target with one medical imaging device and monitoring of the progress of a medical intervention or a medical therapy process or an insertion of a medical device with a second medical imaging device. This again can be particularly useful when employing image guided medical intervention systems such as those introduced by the assignees in US Patent No. 5,647,373, PCT/IL96/00050 and PCT/IL98/00578.

The main object of the present invention is to provide methods and apparatus for combining two or more medical imaging systems (such as an ultrasound and a CT) in medical diagnosis and procedures.

Another object of the present invention is to reduce mechanical constrains between the position of two medical imaging devices used to scan the same target or body volume.

Another object of the present invention is to enable the physician to free hand manipulate part or all of the medical imaging devices used in the same intervention or diagnosis.

Another object of the present invention is to reduce the amount of radiation applied on a patient during diagnostic and medical interventions and/or therapy.

The proposed method and apparatus include a position measuring system that enables the establishment of the relative position between the two or more imaging medical devices and between the image planes/volumes produced by each medical imaging device.

The method and apparatus disclosed in the present invention comprises at least two medical imaging devices, at least a display, a data processor, an image processor, said image processor can be part of the data processor, and a position measuring system comprising position controlling and position measuring components, where the position controlling component can be part of the data processor.

The position measuring system enables establishment of the relative position between the at least two medical imaging devices and between the image planes/volumes produced by said at least two imaging devices.

The data processor receives the information from the position measuring system and uses it for at least one of the following;

a) maneuvering one or more imaging devices in order to scan the interest target within the body according to information available from another medical imaging device, or

b) facilitating image fusing when images of same plane/volume are available from two or more imaging devices.

As a result of the processed data a medical intervention device can be guided for performing medical therapy procedures or inserting a medical device according to information received from one imaging device while monitoring the above operations with the help of another medical imaging device.

The method and apparatus are beneficial in that; they have add-on capabilities and one can define dynamic architectures, and they enable free-hand maneuvering of all or part of the imaging devices.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described by way of the accompanying drawings, wherein like reference numerals and/or characters indicate corresponding or like components. In the drawings:

FIG. 1a pictorially illustrates one form of a system constructed according in accordance with the present invention for cooperative operation of an ultrasound and a computerized topography (CT) apparatus;

FIG. 1b pictorially illustrates the relative position between the scanning beams of the CT and ultrasound in FIG. 1a;

FIG. 2a is a vector diagram which pictorially illustrates the vectors used in calculating the relative position between the scanning beams of the ultrasound and the CT in FIG 1a;

FIG. 2b is a block diagram illustrating the steps involved in calculating the relative position between the scanning beams of the ultrasound and the CT in FIG 1a.;

FIG. 3 pictorially illustrates display functions enabled according to the present invention in relation to FIG. 1a;

FIG. 4a pictorially illustrates one possible position measuring system to be used in accordance to the present invention;

FIG. 4b pictorially illustrates another possible position measuring system to be used in accordance to the present invention;

FIGs. 5a and 5b pictorially illustrate another form of a system constructed according in accordance with the present invention for cooperative operation of an ultrasound and a CT;

FIGs. 6a and 6b pictorially illustrate another form of a system constructed according in accordance with the present invention for cooperative operati n of an ultrasound and a CT;

FIG. 7 illustrates a CT with capability of electronically or mechanically changing its scanning plane;

FIG. 8 is a simplified flowchart illustrating the steps of using in a cooperative mode two medical scanning devices in accordance to the present invention;

FIG. 9 pictorially illustrates one form of a system constructed according in accordance with the present invention for cooperative operation of an ultrasound and a X-Ray;

FIGs. 10a and 10b pictorially illustrate another form of a system constructed according in accordance with the present invention for cooperative operation of an ultrasound and a MRI; and

FIG. 11 pictorially illustrates the reference scanning plane of an MRI.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1a illustrates a first embodiment, exemplary of the present invention. The first embodiment utilizes at least two compatible devices that produce medical images. Here, the image producing devices include an ultrasound apparatus 2, and a computerized tomography (CT) apparatus 4, employed in a cooperative operation. Alternately, the image producing devices could be the same or different devices, or combinations thereof, provided they operate cooperatively with respect to each other and are compatible. For example, these devices may be devices that produce images by ultrasound, computerized tomography (CT), Magnetic Resonance Imaging (MRI), X-ray, endoscopy etc.

Here, for example, images produced by CT 4 of a body 6 (or body volume) of a target 8 in the body 6 (body volume) may be utilized to guide a medical ultrasound driven intervention by accurately pin-pointing an area required to be treated that cannot be imaged as accurately by ultrasound. Also, images produced by the two medical imaging devices may be combined in real-time or off-line to produce the detail required in the area of the image required. The system can be fitted to existing and deployed medical imaging devices without major modifications or adaptations.

Ultrasound 2 and CT 4 are connected to a display 10 via an image processor 12 (optional) contained in data processor 14, for displaying on display 10 at least the images of ultrasound 2 and CT 4. Ultrasound 2 and/or CT 4 may also be connected directly to display 10 via the necessary connections and hardware. Image processor 12 may be part of data processor 14 or can be connected to it.

Ultrasound 2 comprises a main unit 16 connected to a scanning head 18 further referred to as the ultrasound transducer as is known in the art. CT 4 comprises a main unit 20 connected to a scanning head 22, further referred as a CT scanning head. CT scanning head 22 includes X-ray emitter and detector(s) (not shown) as is known in the art. The term scanning head will be used to define the detector and/or emitter component of the medical imaging or scanning device, such as the transducer of an ultrasound or the coils of a MRI, or the X-ray emitter and detector(s) of a CT or an X-ray. Bed 24 may or may not be part of CT imaging device 4.

A position measuring system comprising at least a position sensing controller 26 and position measuring components 28 and 30 is used to measure the relative position between ultrasound transducer 18 and CT scanning head 22. The term position measuring components will define any of the following group: transmitter or receiver or reflector or transceiver or optical indicia or any combination of the above, suitable to be part of a magnetic (for example, in accordance with the systems detailed in U.S. Patents Nos. 4,314,251, 4,054,881) or acoustic (for example, in accordance with the system detailed in U.S. Patent No. 4,124,838) or optic (for example, in accordance with the system detailed in U.S. Patent No. 4,649,504) position measuring system. Position sensing controller 26 can be part of data processor 14.

In order to perform the task of measuring the relative position between ultrasound transducer 18 and CT scanning head 22, position measuring component 28 is attached at a known and fixed position with respect to the ultrasound transducer 18. The attachment can be either directly to the transducer 18 or by means of an extension. Likewise, position measuring component 30 is attached at a known and

fixed position from CT scanning head 22. The term position defines location and/or orientation.

Position sensing controller 26 measures the relative position between position measuring component 28 and position measuring component 30, enabling to calculate the relative position between ultrasound transducer 18 and CT scanning head 22.

Reference is now made to FIG. 1b that shows a detailed view of ultrasound transducer 18, CT scanning head 22 and position measuring components 28 and 30. Items referred to in previous figures are numbered similarly and will not be further described.

Position measuring component 28 is calibrated to ultrasound transducer 18 such that the ultrasound scanning beam 32 is at a known and fixed position with respect to position measuring component 28. Such calibration can be achieved by operating according to PCT application PCT/IL98/00631.

Likewise, position measuring component 30 is calibrated to scanning head 22 such that the CT scanning beam 34 is at a known and fixed position with respect to position measuring component 30. Such calibration can be achieved by operating according to the co-assigned PCT application PCT/IL98/00631.

These calibrations enable calculation of the relative position between ultrasound scanning beam 32 and CT scanning beam 34 based on measuring the relative position between position measuring components 28 and 30, and based on the calibration values defined above. The vector diagram of FIG. 2a and flowchart of FIG. 2b illustrate one possible algorithm to be used for calculating the relative position between the beams of the two medical scanning devices.

Reference to flowchart of FIG. 2b, block 40 shows the result of the calibrating position measuring component 28 to ultrasound transducer 18. Block 42 shows the result of the calibrating position measuring component 28 to ultrasound transducer 18. Blocks 40 and 42 are performed off-line. Block 44 shows the measurement of the relative position of position sensor 28 with respect to position sensor 30. Block 46 shows one possible set of equations (Equations 1 and 2 described below) for calculating the relative position between ultrasound scanning beam 32 and CT scanning beam 34. These equations are:

$$[M]^{US\_S\_B}_{CT\_S\_B} = [M]^{P\_M\_C\_30}_{CT\_S\_B} * [M]^{P\_M\_C\_28}_{P\_M\_C\_30} * \left([M]^{P\_M\_C\_28}_{US\_S\_B}\right)^{T} \quad \text{(Eq. 1)}$$

$$\vec{d}^{\,US\_S\_B}_{CT\_S\_B} = [M]^{P\_M\_C\_30}_{US\_S\_B} * \left([M]^{P\_M\_C\_28}_{P\_M\_C\_30}\right)^{T} * \vec{d}^{\,P\_M\_C\_30}_{CT\_S\_B} + [M]^{P\_M\_C\_28}_{US\_S\_B} * \left\{\vec{d}^{\,P\_M\_C\_28}_{P\_M\_C\_30} - \vec{d}^{\,P\_M\_C\_28}_{US\_S\_B}\right\} \quad \text{(Eq. 2)}$$

The indexes and parameters in the above equations are according to vector diagram of FIG. 2a and flowchart of FIG. 2b.

In one exemplary use of the invention target 8 within a body 6 is scanned with the ultrasound transducer 18. The position of the CT scanning beam 34 is calculated with respect to the ultrasound beam 32 as explained above.

Referring to FIG. 3, the relative position of CT scanning beam 34 with respect to the ultrasound scanning beam 32 is indicated to the operator in a 2-D and/or 3-D fashion on display 10, by boxes 60 and 62 respectively. The above relative position can also be superimposed on the ultrasound image 64, including the image of target 8', for example in the form of a crossing line 66 and data box 68. The amount of deviation of CT scanning beam 34 from ultrasound scanning beam 32 can also be displayed to the operator, for example in the from of angles and distances, as in box 68. This enables the operator to first position ultrasound transducer 18 such as to view a target 8 or a desired scanning plane and then position the CT scanning head 22 such that the two scanning beams 34 and 32 coincide, or such that CT scanning beam 32 views target 8 or part of it. It is then possible to remove ultrasound transducer 18 and scan body 6 by CT 4 such that CT scanning beam 34 is scanning target 8 or a plane/volume of interest.

Additionally, target 8 can be marked by the operator on the image produced by the ultrasound 2 as shown on the display 10. This can be performed for example, by marking software in conjunction with a mouse or by other standard computer based interactive procedure. The position of CT scanning head 22 and scanning beam 34 can then be calculated with respect to the target 8, thus enabling the operator to position CT scanning beam 34 so as to view the target 8.

Alternately, the operator can scan body 6 by ultrasound 2 and based on ultrasound image 64 on display 10 a reference plane can be indicated by the operator, for example in the form of clicking a button. This enables to define a reference plane/volume of body 6 to be then scanned at a greater resolution by CT 4.

Thus, the operator may manually command the maneuvering of the CT scanning head 22 in position based on the instructions available on the display 10. Alternately, the system can be made fully automatic and the maneuvering commands may be issued from data processor 14 by an optional link to CT 4.

In applications requiring very high accuracy it is necessary to constrain body 6 in order to avoid small movements between scanning body 6 by ultrasound 2 and scanning body 6 by CT 4. In most applications this requirement is not necessary.

An additional implementation to be used in connection to the present invention may be to correlate and/or fuse ultrasound image/information with CT image/information to produce a superimposed or combined image/information, also known as a "fused" image, that has the advantages of both technologies. Body volume 6 is scanned by CT 4 producing high resolution image/information. Target 8 is defined by the operator on CT image as displayed on display 10. Target 8 is then scanned by ultrasound transducer 18. The position of the ultrasound scanning beam 32 is determied by the position measuring components (as detailed above) as is the position of the CT scanning beam 34. Based on the measured positions of the ultrasound and CT scanning beams 32, 34, as determined in accordance with the present invention, the ultrasound image information may be correlated or fused with CT image information by the image processor 12, employing conventional image processing algorithms and techniques. By correlating or fusing these images (from the ultrasound and CT scanning beams, respectively), the displayed ultrasound image may be enhanced. Also, the image correlation and/or fusing may be used in an iterative mode in order to improve the calculation of the relative position between ultrasound scanning beam 32 and the CT scanning beam 34.

Reference is now made to FIG. 4a that illustrates a magnetic position measuring system to be used in accordance with an exemplary embodiment of the present invention. Similar items in previous figures have similar numbers and will not be further described.

In this exemplary embodiment position measuring component 28 is a receiver 28' being attached to ultrasound transducer 18 and position measuring component 30 is a transmitter 30' being attached to CT scanning head 22 by an arm 80'. Transmitter 30' is transmitting AC or DC magnetic/electromagnetic signals to receiver 28'. The output of receiver 28' is transmitted by wire or wireless connections to position sensing controller 26 enabling to calculate the relative position of receiver 28' with respect to transmitter 30'. Alternately, position measuring component 28 could be a transmitter and position measuring component 30 could be a receiver.

Reference is now made to FIG. 4b wherein an optical position measuring system is employed in accordance with another exemplary embodiment of the present invention. Similar items in previous figures have similar numbers and will not be further described. A stereo vision charge coupled device (CCD) camera 84' is positioned on an arm 86' at a first reference location. Position measuring component 28 includes a cluster of LED's 28'' being attached to ultrasound transducer 18 by an arm 88' and position measuring component 30 includes a cluster of LED's 30'' being attached to CT scanning head 22 by an arm 80''. The relative position of cluster of LED's 28'' is measured with respect to the CCD camera 84' (first reference location), and also the relative position of cluster of LED's 30'' is measured with respect to CCD camera 84' (first reference location). It is therefore possible to calculate from the above measurements the relative position of cluster of LED's 30'' with respect to

cluster of LED's 28'' and hence, the relative positi n between ultrasound scanning beam 32 and CT scanning beam 34.

The above detailed position measuring systems enable measurement of the relative position between ultrasound transducer scanning beam 32 and CT scanning beam 34 can be optical, acoustic or magnetic. The relative position between position measuring components 28 and 30 can be measured directly, for example, when one of the components is a receiver and the other one is a transmitter as illustrated in the exemplary embodiment in FIG. 4a. Alternately, the relative position between position measuring components 28 and 30 can be calculated indirectly, for example, by measuring the position of each with respect to a reference location as illustrated in the exemplary embodiment in FIG. 4b.

When making these indirect calculations, a third position measuring component 84 (illustrated in FIG. 4b by a stereo Charge Coupled Device (CCD) 84') is in operative communication with position measuring components 28 and 30, this CCD 84 is positioned at a first reference location. The first reference location may be fixed and known. Alternately, the first reference position can be movable and unknown. Optionally, the first reference position can be attached to the bed 24.

Position measuring components 28, 30 and 84 (if part of the system) may be any of the following group: transmitter or receiver or reflector or transceiver or optical indicia or any combination of the above, suitable to be part of a magnetic or acoustic or optic position measuring system.

Position sensing controller may communicate with at least one or all of position measuring components 28, 30 and 84 (if part of the system) by wired or wireless links.

Reference is now made to FIGs. 5a and 5b, which illustrate a system configured according to another exemplary embodiment of the present invention. Similar items to those in previous figures have similar numbers and will not be further described. In this exemplary embodiment, position measuring component 30'' is detached from CT scanning head 22 and attached via an arm 80'' at a known and fixed position with respect to bed 24. The position of bed 24 is fully calibrated with respect to CT scanning head 22, this calibration in accordance with conventional CT devices that employ beds or the like.

As a result of this calibration, the position of the CT scanning beam 34 is known with respect to position measuring component 30' at all times and all positions of bed 24. If movement of bed 24 is controlled by CT main unit 20, the information regarding the movement of bed 24 may be transferred from CT main unit 20 to data processor 14. Alternately, the movement of bed 24 may be controlled directly by data processor 14. Thus, the modalities of employing in operative cooperation ultrasound 2 and CT 4 are similar to those enabled by the system illustrated in FIG. 1a.

Alternately, with reference to FIGs. 6a and 6b, an indirect position measuring system may be employed comprising position measuring component 84 at a first reference location. In this exemplary embodiment position measuring component 84 could be a transmitter and position measuring components 30' and 28 could be receivers all part of a magnetic position measuring system. The illustrated indirect position measuring system enables to monitor the movement of bed 24 directly through position sensing controller 26.

Reference is now made to FIG. 7 illustrating a CT scanning head 22 wherein CT scanning plane 34 may be changed electronically or mechanically. Similar items to those in previous figures have similar numbers and will not be further described.

In this exemplary embodiment position measuring component 30 may only be calibrated to a reference CT scanning plane 34', but not to all possible CT scanning planes. Information regarding the relative position between any CT scanning plane 34 with respect to CT reference scanning plane 34' will be outputted from the CT main unit 20 to data processor 14 enabling to calculate the position of the actual CT scanning plane 34 with respect to position measuring component 30. Thus, the modalities of employing in operative cooperation ultrasound 2 and CT 4 are similar to those enabled by the system illustrated in FIG. 1a, as detailed above.

Reference is now made to FIG. 8 which is a flow-chart illustration of the steps required in order to operate two medical imaging devices in operative cooperation in accordance to the present invention. At step 90, it is measured the relative position between position measuring components 28 and 30 (P.M.C. in FIG. 8) being at known positions with respect to ultrasound transducer 18 and CT scanning head 22 respectively. At step 94 it is calculated the relative position between ultrasound scanning plane/volume 32 and CT scanning plane/volume 34. The calculation at step 94 is based on knowing the position of CT scanning plane/volume 34 with respect to position measuring component 30 and the position of CT scanning plane/volume 34 with respect to position measuring component 28 (step 92). The relative position information calculated in step 92 may also be used in other medical procedures (step 96) that is optional, but preferred, for example in image guided interventions, such as described in co-assigned U.S. Patent No. 5,647,373. The relative position information

calculated in step 92 may also be used in order to instruct the positioning of CT scanning head 22 and ultrasound transducer 18 with respect to each other (step 120). Once the relative position between the scanning planes/volume is calculated the images from CT 4 and ultrasound 2 may be correlated and or fused in optional, but highly preferred step 98. The superimposed image/information resulting of step 98 may be optionally used to improve calculation at step 92 in an iterative mode. The superimposed image/information resulting of step 98 may also be used in other medical procedures (step 96) or in order to instruct the positioning of CT scanning head 22 and ultrasound transducer 18 with respect to each other (step 120).

The imaging options 100 are non-exhaustively, listed as follows. The image from CT 4 and ultrasound 2 may be displayed individually (steps 102 and 104), the relative position between CT and ultrasound scanning beams may be displayed (step 106) and the result of image fusing, at step 98 may also be displayed (step 108).

In addition to and interacting with display functions 100, there are various ancillary functions such as optionally marking a target 8 (step 112) on the image produced by one of the imaging devices as appearing on display 10. Then the position of target 8 may be calculated within the scanning beam of the medical imaging device. (step 114). Additionally/alternately a reference plane/volume may be marked or signaled according to the image produced by one of the imaging device (step 116). The position of the reference plane/volume may then be calculated (step 118). The data in steps 114 and/or 118 may be optionally used in order to instruct the positioning of CT scanning head 22 and ultrasound transducer 18 with respect to each other (step 120).

Reference is now made to FIG. 9, which illustrates an additional embodiment of the present invention. Similar items to those shown in previous figures have similar numbers and will not further be described. The second embodiment illustrates an ultrasound 2, and a X-Ray 138 to be used in cooperative operation according to the present invention. The X-Ray imaging device comprises X-Ray main unit 140 and X-Ray scanning head 142 including emitter 142' and detector 142'. X-Ray scanning head 142 is mounted on a movable and adjustable arm 144. Bed 24 may or may not be part of X-Ray imaging device 138.

Position measuring component 30 is attached at a known and fixed positions from X-Ray scanning head 142. Additionally, position measuring component 30 is calibrated to the scanning head 62 such that it is at a known position from the scanning volume of the X-Ray. Such calibrations can be achieved by operating according to patent application PCT/IL98/00631. The relative position between ultrasound transducer scanning beam 44 and the X-ray scanning volume 146 can be calculated as described in the first embodiment based on direct measurement between position measuring components 28 and 30.

An additional position measuring component 84 is placed at a reference location on an arm 86. This position measuring component 84 is in cooperative communication with position measuring components 28 and 30. Thus, the position of ultrasound transducer 42 and of the X-Ray scanning head 62 are measured with respect to the reference position similar to the calculation described in relation to FIG. 4b. Body 6 is fixed so as to avoid movement during the procedure. X-Ray scanning head 142 is positioned in order to view target 8 in the body 6 or body volume at two different positions. The position of X-Ray scanning head 142 is measured with

respect to reference position thus enabling to correlate the two images into stereo information in order to receive a 3D image of the scanned body 6. Algorithms for creating such 3D image/information are conventional in the art.

In one exemplary use of present invention, the operator may indicate target 8 on the image received from the X-Ray 138 for example, by marking it with a mouse on the display 10 (as described herein above with reference to FIGs. 1-3). The relative position of target 8 can be calculated with respect to the reference point. Ultrasound transducer 18 is then applied to body volume 6 and its position is measured with respect to the reference position. Thus, it is possible to calculate the position of ultrasound scanning plane 32 with respect to the image volume received from X-Ray 138 and target 8.

Alternately, the body volume 6 is first imaged by ultrasound in order to establish a desired reference plane/volume that includes a target 8. The operator selects a reference plane, in accordance with the procedures detailed above. Alternately, the operator the operator indicates target 8 for example by marking it on the display 10, using conventional marking software, as described above. Data processor 14 stores the position of target 8 or of reference plane with respect to the reference location. Ultrasound transducer 22 is then removed and the position of X-Ray scanning head 34 is calculated with respect to reference plane or target 8. Thus, it is then possible to position X-Ray scanning head 142 in an optimal way at two different positions so as two view target 8 and afterwards produce a 3D image/information.

Additional modalities of employing in operative cooperation ultrasound 2 and X-Ray 138 are similar to those described for the system illustrated in FIGs. 1a 7 and described above.

Reference is now made to FIGs. 10a, 10b and 11 which illustrate an additional embodiment of the present invention. Similar items to those shown in previous figures have similar numbers and will not further be described. The third embodiment illustrates an ultrasound 2 and an MRI 138 to be used in cooperative operation. MRI 138 comprises MRI main unit 160 and MRI scanning head 162. Bed 24 may or may not be part of MRI imaging device 158.

The cooperative operation between ultrasound 2 and MRI 158 is similar to that in the previous embodiments except for the necessity to operate the ultrasound 2 above a minimal required distance from MRI scanning head 162 (depending on the strength of the magnetic field of MRI 158 and ultrasound 2 compatibility). Thus, body 6 is scanned by ultrasound transducer 18 such that ultrasound 2 (and particularly ultrasound transducer 18) is above the minimal required distance from MRI scanning head 162. This minimal required distance varies from one type of MRI to another. In the exemplary embodiment illustrated in FIGs. 10a and 10b the minimal required distance requires to move body 6 on bed 24 a certain distance from the MRI scanning area. According to the exemplary embodiment in FIGs. 10a, 10b and 11, position measuring component 30 is attached through an arm 80''' at a known and fixed position with respect to bed 24.

The necessity to move bed 24 between MRI scanning and ultrasound image requires measurement of the movement of bed 24 by one of the methods described herein above in connection to FIGs. 5a, 5b, 6a and 6b. The position of bed 24 may be calibrated with respect to MRI scanning head 162 such that position of MRI reference scanning plane 164' is known with respect to position measuring component 30.

MRI scanning plane 164 may be changed by electronic means. Thus, position measuring component 30 may only be calibrated to a reference MRI scanning plane

164', and not to all possible MRI scanning planes 164. Information regarding the relative position between the actual MRI scanning plane 164 with respect to MRI reference scanning plane 164' will be outputted from MRI main unit 160 to data processor 14. Thus the position of actual MRI scanning plane 164 with respect to position measuring component 30 can be calculated as described herein above with respect to FIG. 7.

The cooperative operation of ultrasound 2 and MRI 158 may also be obtained by using alternative systems herein above described in connection to embodiments illustrated in FIGs. 1a – 8.

Thus, the modalities of employing in operative cooperation ultrasound 2 and MRI 158 are similar to those enabled by the system illustrated in above embodiments illustrated in FIGs. 1a - 8.

While the invention has been described with respect to several preferred embodiments, it will be appreciated that these are set forth merely for purposes of example, and that many variations, modifications and applications of the invention may be made. Accordingly, the scope of the invention is defined by the claims which follow.

CLAIMS

1. A method enabling free of predefined mechanical constraints cooperative operation of two or more medical scanning devices useful in medical diagnosis and/or medical therapy planning and/or medical intervention planning and/or medical therapy and/or medical intervention and/or medical procedures, the method comprising the steps of:

scanning a body volume/plane with at least one first medical scanning device;;

sensing the position of an at least one second medical scanning device with respect to said at least first medical scanning device by means of a position measuring system comprising position measuring controller and position measuring components;

scanning part or all of said body volume/plane with at least one second medical scanning device;

calculating the relative position of said at least one second medical scanning device and/or relative position of the scanning plane/volume produced by said at least one second medical scanning device with respect to said at least one first medical scanning device and/or with respect to the scanning plane/volume produced by said at least one first medical scanning device;

displaying on at least one display screen said calculation in a cooperative way to the medical operator.

2. The method according to claim 1 where the at least one first medical scanning device is one.

3. The method according to claim 1 where the at least one second medical scanning device is one.

4. The method according to claim 1 where the at least one display screen is one.

5. The method according to claim 1 where said at least one first and said at least one second medical scanning device operate sequentially.

6. The method according to claim 1 where said at least one first and said at least one second medical scanning device operate simultaneously and/or intermittently.

7. The method of claim 1 where the at least one first medical scanning device is one of the group X-Ray, CT, MRI or ultrasound.

8. The method of claim 1 where the at least one second medical scanning device is one of the group X-Ray, CT, MRI or ultrasound.

9. The method of claim 1 where the at least one second medical scanning device is an ultrasound.

10. The method of claim 1 where the at least one first medical scanning device is an ultrasound.

11. The method of claim 1 where the position measuring system is magnetic.

12. The method of claim 1 where the position measuring system is optic.

13. The method of claim 1 where the position measuring system is acoustic.

14. The method of claim 1 where the step of sensing the position of an at least one second medical scanning device with respect to said at least first medical scanning device is performed by means of wired communication.

15. The method of claim 1 where the step of sensing the position of an at least one second medical scanning device with respect to said at least first medical scanning device is performed by means of wireless communication.

16. The method according to claim 1 where the position of the said at least one second medical scanning device is calculated with respect to said at least one first medical scanning device.

17. The method according to claim 1 where the position of the said at least one second medical scanning device is calculated with respect to the scanning plane/volume produced by said at least one first medical scanning device.

18. The method according to claim 1 where the position of the scanning plane/volume produced by said at least ne second medical scanning device is calculated with respect to said at least one first medical scanning device.

19. The method according to claim 1 where the position of the scanning plane/volume produced by said at least one second medical scanning device is calculated with respect to the scanning plane/volume produced by said at least one first medical scanning device.

20. The method according to claim 1 where the scanned plane/volume produced by said at least one first medical scanning device is correlated and/or fused by image processing tools with the scanned plane/volume produced by said at least one second medical scanning device.

21. The method according to any of the claims 20 where said information correlation and/or fusing is used to improve said calculation of relative position between the scan plane/volume produced by said at least one first medical scanning device and the scan plane/volume produced by said at least one second medical scanning device.

22. The method according to claim 21 where said improvement of said calculation and said information correlation is performed in an iterative way.

23. The method according to claim 1 further comprising the step of indicating to said position sensing system the position of a target by marking said target on said at least one display screen.

24. The method according to claim 1 further comprising the step of indicating to said position sensing system the position of a target by detecting said target by image processing tools.

25. The method according to claim 1 further comprising the step of indicating to said position sensing system the position of a reference plane/volume by marking said reference plane/volume on said at least one display screen.

26. The method according to claim 1 further comprising the step of indicating to said position sensing system the position of a reference plane/volume by manually producing an indicia in the form of a signal.

27. The method according to any of the claims 23-26, where the position of the said at least one second medical scanning device is calculated with respect to said target and/or said reference plane/volume.

28. The method according to claim 1 where the position of the scanning plane/volume produced by the said at least one second medical scanning device is calculated with respect to said target and/or said reference plane/volume.

29. The method according to claim 1 and further comprising the step of indicating on said at least one display screen the actual progressive motion of said at least one second medical scanning device towards said target and/or reference plane/volume.

30. The method according to claim 1 and further comprising the step of indicating on said at least one display screen the deviation of said at least one second medical imaging device or scanning plane/volume produced by said at least one second medical scanning device from said target and/or from said reference plane/volume.

31. The method according to claim 1 and further comprising the step of adjusting the position of said at least one second scanning device so as to cause it to include in its scan plane/volume said target or to cause that its scan plane/volume coincide with said reference plane/volume.

32. Apparatus enabling free of predefined mechanical constraints cooperative operation of two or more medical scanning devices useful in medical diagnosis and/or medical therapy planning and/or medical intervention planning and/or medical therapy and/or medical intervention and/or medical procedures, apparatus comprising:

at least one first medical scanning device;

at least one second medical scanning device;

a position measuring system comprising at least the following: a position sensing controller and at least one first position measuring component at a known position with respect to said at least one first medical scanning device and at least one second position measuring component at a known position with respect to said at least one second medical scanning device;

a data processor for receiving data from the position sensing controller for calculating the relative position of said at least one second medical scanning device and/or relative position of the scanning plane/volume produced by said at least one second medical scanning device with respect to said at least one first medical scanning device and/or with respect to the scanning plane/volume produced by said at least one first medical scanning device, said data processor displaying on at least one display screen said calculation in a cooperative way to the medical operator.

33. Apparatus according to claim 32 where the at least one first medical scanning device is one.

34. Apparatus according to claim 32 where the at least one second medical scanning device is one.

35. Apparatus according to claim 32 where the at least one display screen is one.

36. Apparatus according to claim 32 where said at least one first and said at least one second medical scanning device operate sequentially.

37. Apparatus according to claim 32 where said at least one first and said at least one second medical scanning device operate simultaneously and/or intermittently.

38. Apparatus of claim 32 where the at least one first medical scanning device is one of the group X-Ray, CT, MRI or ultrasound.

39. Apparatus of claim 32 where the at least one second medical scanning device is one of the group X-Ray, CT, MRI or ultrasound.

40. Apparatus of claim 32 where the at least one second medical scanning device is an ultrasound.

41. Apparatus of claim 32 where the at least one first medical scanning device is an ultrasound.

42. Apparatus of claim 32 where the position measuring system is magnetic.

43. Apparatus of claim 32 where the position measuring system is optic.

44. Apparatus of claim 32 where the position measuring system is acoustic.

45. Apparatus of claim 32 where the step of sensing the position of an at least one second medical scanning device with respect to said at least first medical scanning device is performed by means of wired communication.

46. Apparatus of claim 32 where the step of sensing the position of an at least one second medical scanning device with respect to said at least first medical scanning device is performed by means of wireless communication.

47. Apparatus according to claim 32 where the position of the said at least one first position measuring component is on said at least one first medical scanning device.

48. Apparatus according to claim 32 where the position of the said at least one second position measuring component is on said at least one second medical scanning device.

49. Apparatus according to claim 32 where said position sensing controller is included in the data processor.

50. Apparatus according to claim 32 where said at least one first position measuring component and said at least one second position measuring component work in operative communication.

51. Apparatus according to claim 50 where said calculation is based on the operative communication between said at least one first position measuring component and said at least one second position measuring component.

52. Apparatus according to claim 32 where said position measuring system additionally comprises at least one third position measuring component being placed at a first reference location;

said at least one third position measuring component being in operative communication with said at least one first position measuring component and said at least one second position measuring component.

53. The system of claim 52 where said operative communication between said at least one first position measuring component and said at least one third position measuring component enable to measure the position of said at least one first medical scanning device with respect to said first reference location;

and said operative communication between said at least one second position measuring component and said at least one third position measuring component enable to measure the position of said at least one second medical scanning device with respect to said first reference location.

54. The system of claim 52 where said first reference location is known.

55. The system of claim 52 where said first reference location is unknown.

56. Apparatus according to claim 32 where the position of the said at least one second medical scanning device is calculated with respect to said at least one first medical scanning device.

57. Apparatus according to claim 32 where the position of the said at least one second medical scanning device is calculated with respect to the scanning plane/volume produced by said at least one first medical scanning device.

58. Apparatus according to claim 32 where the position of the scanning plane/volume produced by said at least one second medical scanning device is calculated with respect to said at least one first medical scanning device.

59. Apparatus according to claim 32 where the position of the scanning plane/volume produced by said at least one second medical scanning device is calculated with respect to the scanning plane/volume produced by said at least one first medical scanning device.

60. Apparatus according to claim 32 where the scanned plane/volume produced by said at least one first medical scanning device is correlated and/or fused by image processing tools with the scanned plane/volume produced by said at least one second medical scanning device.

61. Apparatus according to any of the claims 60, where said information correlation and/or fusing is used to improve said calculation of relative position between the scan plane/volume produced by said at least one first medical scanning device and the scan plane/volume produced by said at least one second medical scanning device.

62. Apparatus according to claim 61 where said improvement of said calculation and said information correlation is performed in an iterative way.

63. Apparatus according to claim 32 further comprising the step of indicating to said position sensing system the position of a target by marking said target on said at least one display screen.

64. Apparatus according to claim 32 further comprising the step of indicating to said position sensing system the position of a target by detecting said target by image processing tools.

65. Apparatus according to claim 32 further comprising the step f indicating to said position sensing system the position of said reference plane/volume by marking said reference plane/volume on said at least one display screen.

66. Apparatus according to claim 32 further comprising the step of indicating to said position sensing system the position of said reference plane/volume by manually producing an indicia in the form of a signal.

67. Apparatus according to any of the claims 62-65, where the position of the said at least one second medical scanning device is calculated with respect to said target and/or said reference plane/volume.

68. Apparatus according to claim 32 where the position of the scanning plane/volume produced by the said at least one second medical scanning device is calculated with respect to said target and/or said reference plane/volume.

69. Apparatus according to claim 32 and further comprising the step of indicating on said at least one display screen the actual progressive motion of said at least one second medical scanning device towards said target and/or reference plane/volume.

70. Apparatus according to claim 32 and further comprising the step of indicating on said at least one display screen the deviation of said at least one second medical imaging device or scanning plane/volume produced by said at least one second medical scanning device from said target and/or from said reference plane/volume.

71. Apparatus according to claim 32 and further comprising the step of adjusting the position of said at least one second scanning device so as to cause it to include in its scan plane/volume said target or to cause that its scan plane/volume coincide with said reference plane/volume.

ABSTRACT

Systems and methods for medical diagnostic and for medical guided interventions using multiple imaging systems are introduced. These systems and methods recognize the need for a relatively simple and modular way of combining information available from two or more medical imaging apparatus in medical diagnosis and in image guided surgery and therapy. Particularly these methods enable to minimize mechanical constraints involved in a cooperative operation of several medical scanning devices.

The apparatus and methods introduced in the present invention enable to measure the relative position between different medical imaging devices and between the image planes and/or image volumes produced by them by means of using a position measuring system based with attachable position measuring components. This facilitates image fusing when images of the same plane/volume are available from different medical imaging systems. Additionally/alternately it enables to position a second medical imaging device over a desired area/volume according to information received from the image produced by the first medical imaging device.

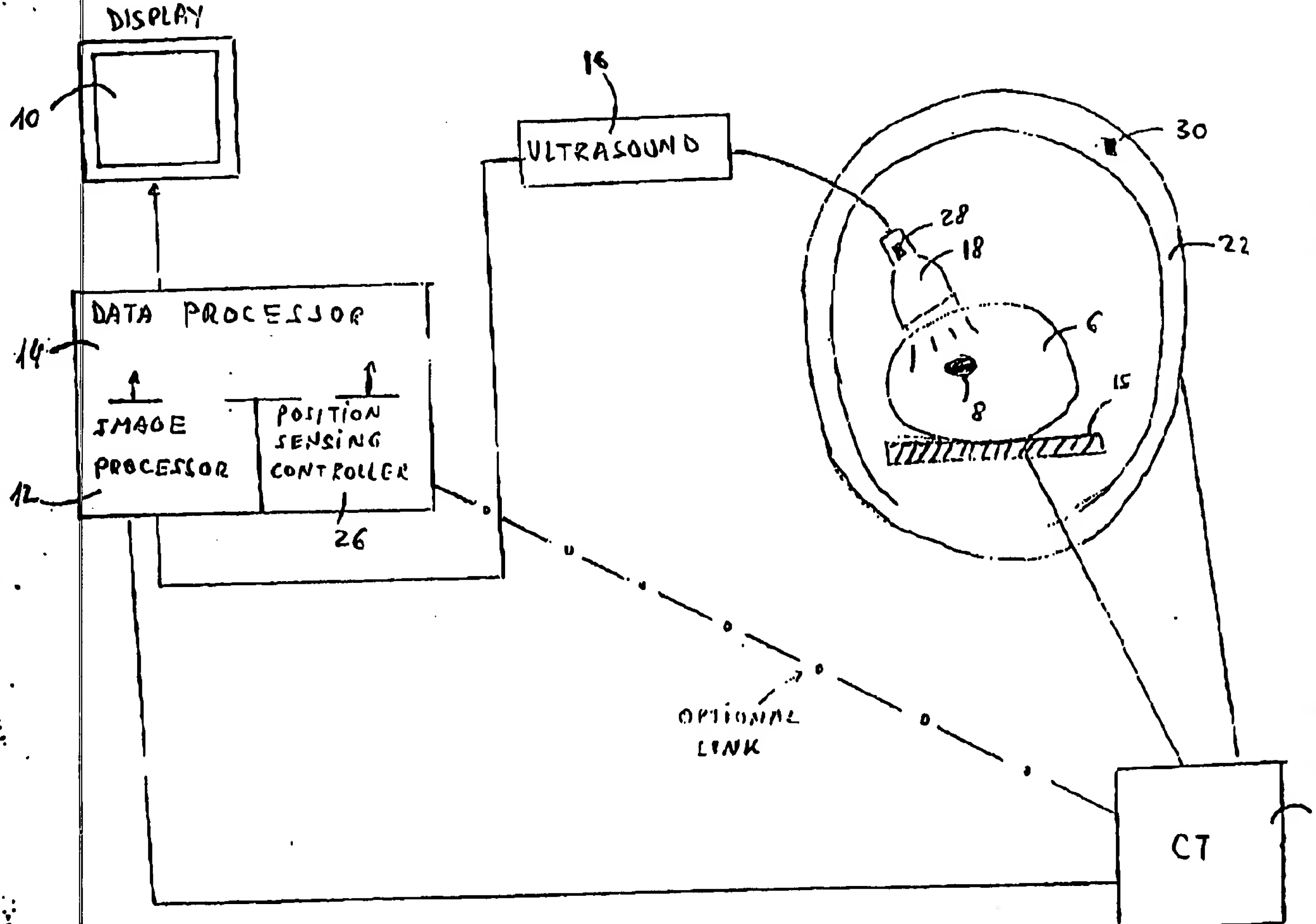
DISPLAY
10
14
DATA PROCESSOR
IMAGE PROCESSOR
12
POSITION SENSING CONTROLLER
26
16
ULTRASOUND
30
28
18
22
6
8
15
OPTIONAL LINK
CT
20

FIG. 1a

09127367.033199

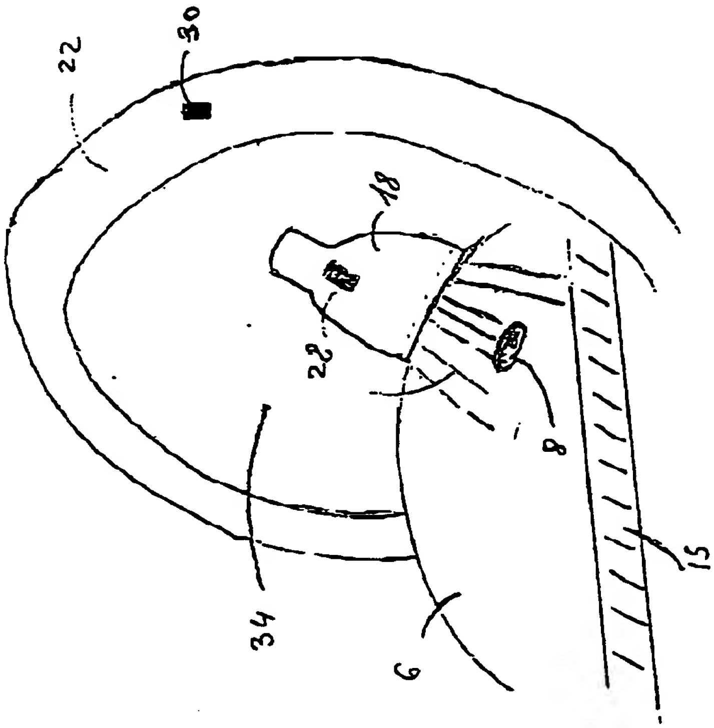

FIG. 1b

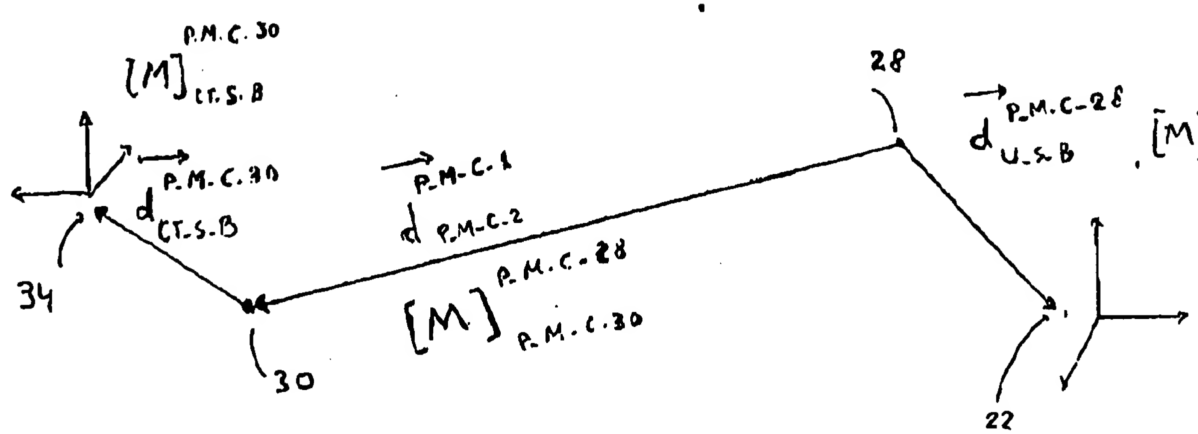
[M] P.M.C.30 CT.S.B
d P.M.C.30 CT.S.B
34
30
d P.M.C.1 P.M.C.2
[M] P.M.C.28 P.M.C.30
28
d P.M.C.28 U.S.B
[M] P.M.C.28 U.S.B
22

FIG. 2a

Calculate the position of the Ultrasound scanning beam with respect to position measuring component 28

vector : $\vec{d}^{\,P.M.C.28}_{US.S.B}$, $[M]^{P.M.C.28}_{US.S.B}$ orientation matrix

40

OFF-LINE

Calculate the position of the CT scanning beam with respect to position measuring component 30

vector : $\vec{d}^{\,P.M.C.30}_{CT.S.B}$, $[M]^{P.M.C.30}_{CT.S.B}$ orientation matrix

42

Measure the position of position measuring component 30 with respect to position measuring component 28

vector : $\vec{d}^{\,P.M.C.28}_{P.M.C.30}$, $[M]^{P.M.C.28}_{P.M.C.30}$ orientation matrix

44

46

Calculate the position of the CT scanning beam with respect to the ultrasound scanning beam

vector $\vec{d}^{\,US.S.B}_{CT.S.B}$, $[M]^{US.S.B}_{CT.S.B}$ orientation matrix

$$[M]^{US.S.B}_{CT.S.B} = [M]^{P.M.C.30}_{CT.S.B} \cdot [M]^{P.M.C.28}_{P.M.C.30} \cdot \left([M]^{P.M.C.28}_{US.S.B}\right)^T$$

$$\vec{d}^{\,US.S.B}_{CT.S.B} = \left[M^{P.M.C.28}_{US.S.B}\right] \cdot \left(\left([M]^{P.M.C.28}_{P.M.C.30}\right)^T \cdot \vec{d}^{\,P.M.C.30}_{CT.S.B} + [M]^{P.M.C.28}_{US.S.B} \cdot \left\{ \vec{d}^{\,P.M.C.28}_{P.M.C.30} - \vec{d}^{\,P.M.C.28}_{US.S.B} \right\}\right.$$

FIG 2b

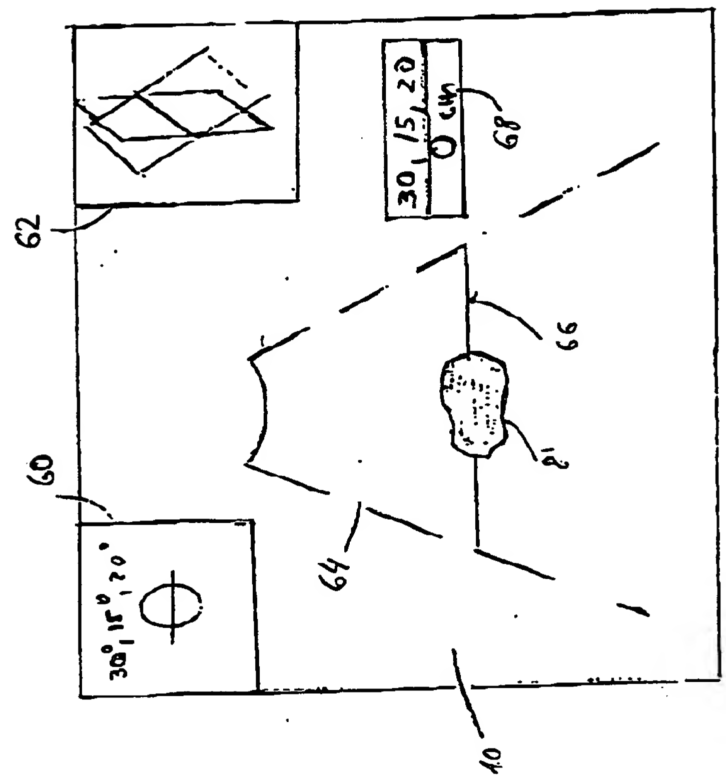

FIG. 3

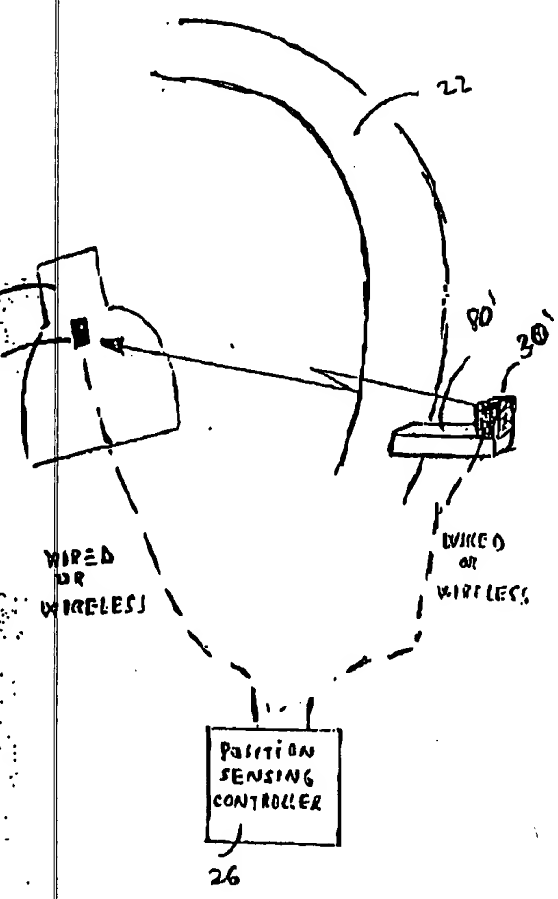
22
18
28'
80'
30'
WIRED OR WIRELESS
WIRED OR WIRELESS
POSITION SENSING CONTROLLER
26

FIG. 4a

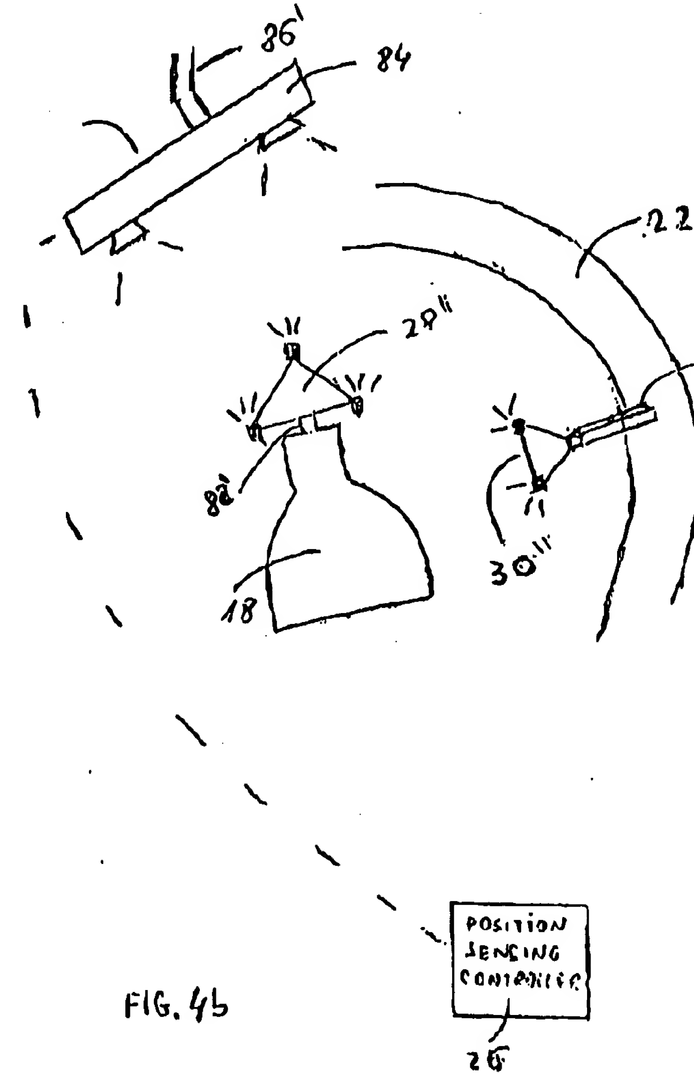
86'
84
22
28''
80''
82'
18
30''
POSITION SENSING CONTROLLER
26

FIG. 4b

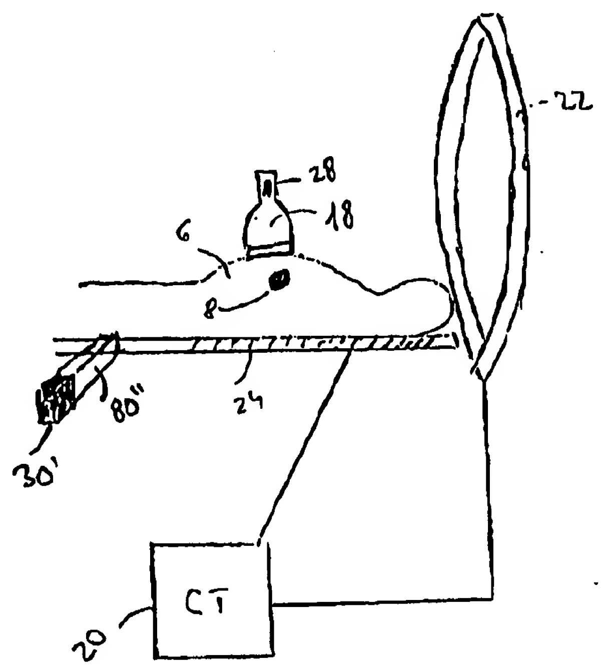

FIG 5a

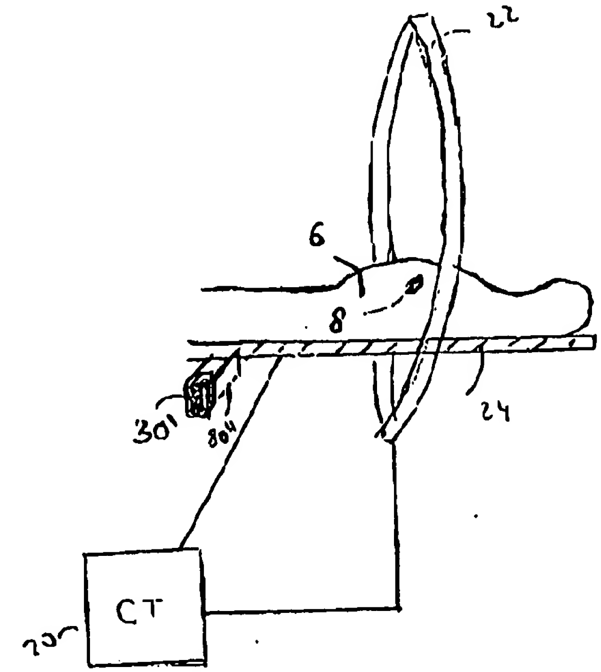

FIG. 5b

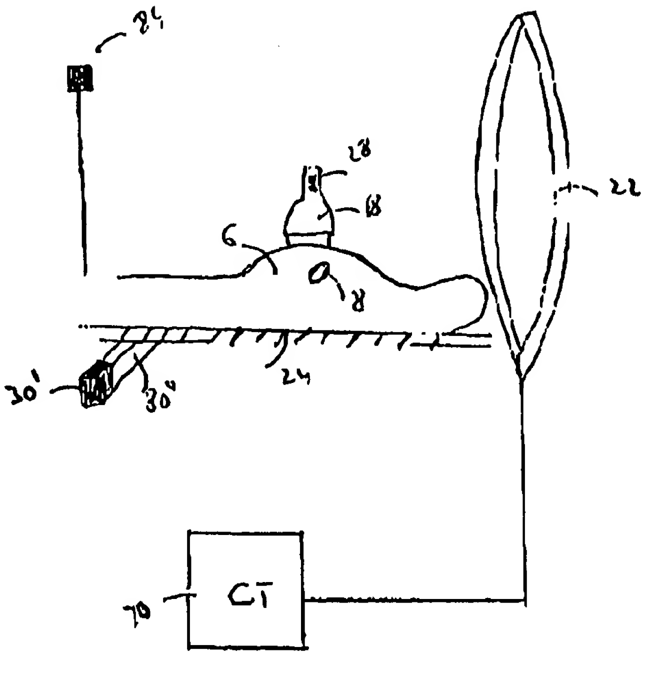

FIG. 6a

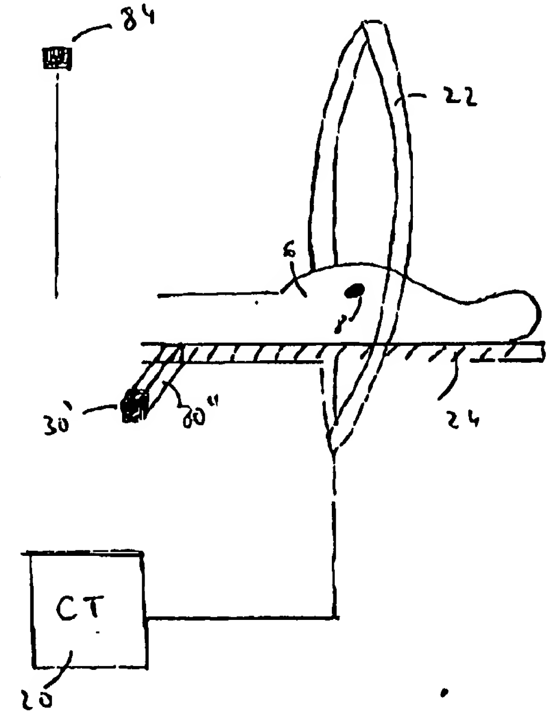

FIG. 6b

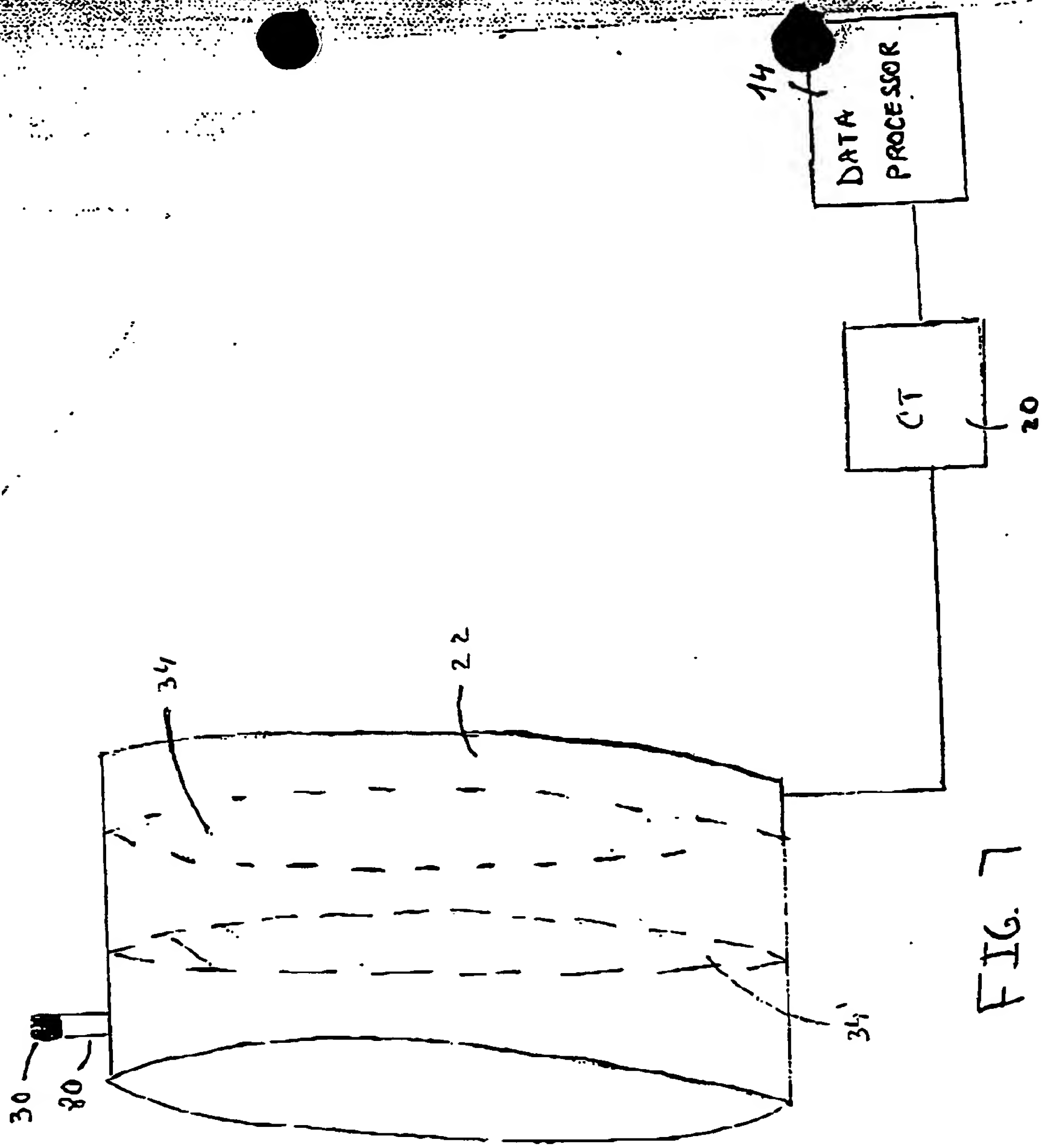

FIG. 7

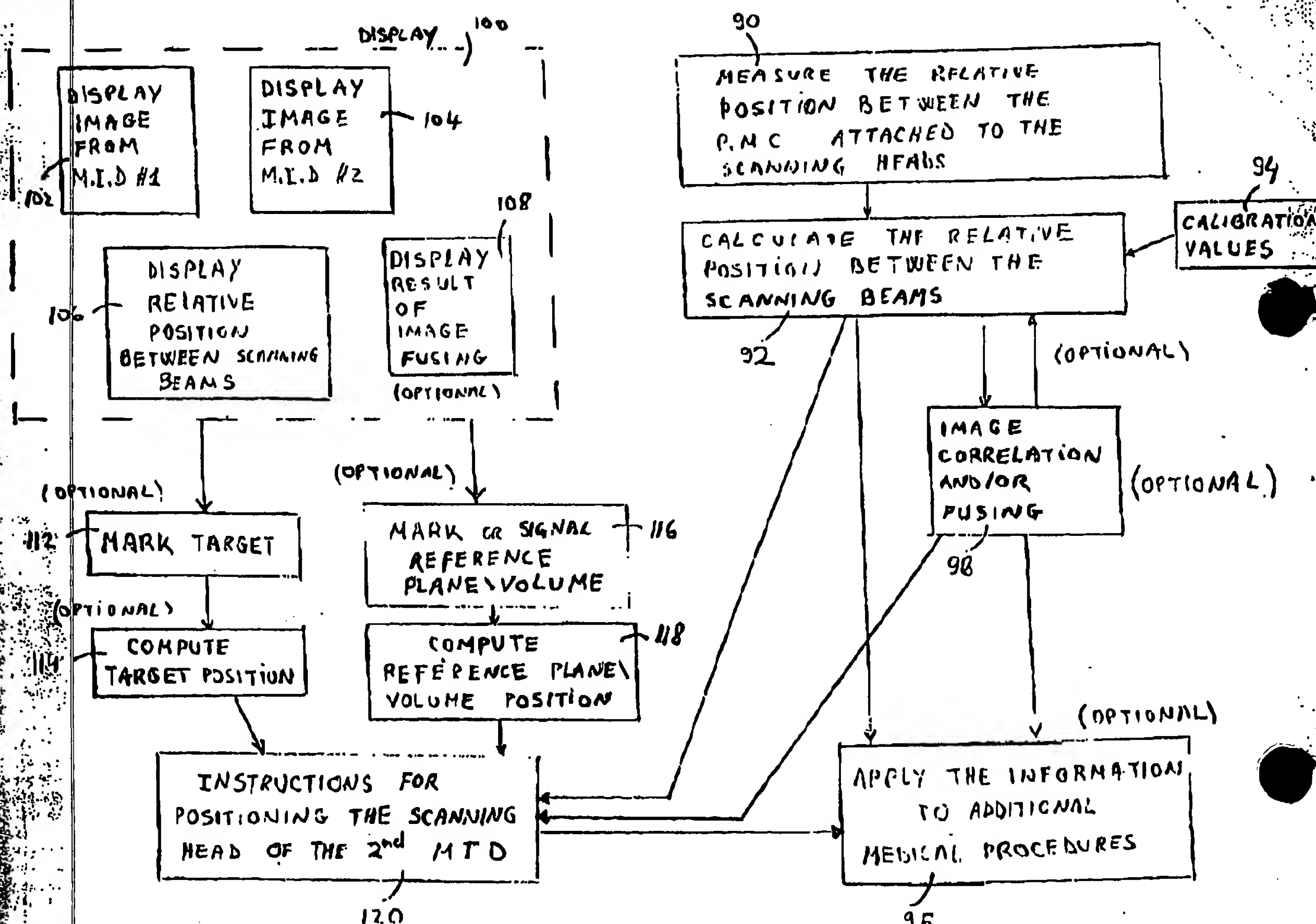
DISPLAY...
100
DISPLAY IMAGE FROM M.I.D #1
102
DISPLAY IMAGE FROM M.I.D #2
104
DISPLAY RELATIVE POSITION BETWEEN SCANNING BEAMS
106
DISPLAY RESULT OF IMAGE FUSING
108
(OPTIONAL)
MEASURE THE RELATIVE POSITION BETWEEN THE P.M.C ATTACHED TO THE SCANNING HEADS
90
CALCULATE THE RELATIVE POSITION BETWEEN THE SCANNING BEAMS
92
CALIBRATION VALUES
94
(OPTIONAL)
IMAGE CORRELATION AND/OR FUSING
98
(OPTIONAL)
(OPTIONAL)
MARK TARGET
112
(OPTIONAL)
COMPUTE TARGET POSITION
114
(OPTIONAL)
MARK OR SIGNAL REFERENCE PLANE\VOLUME
116
COMPUTE REFERENCE PLANE\VOLUME POSITION
118
INSTRUCTIONS FOR POSITIONING THE SCANNING HEAD OF THE 2nd MTD
120
(OPTIONAL)
APPLY THE INFORMATION TO ADDITIONAL MEDICAL PROCEDURES
96

FIG. 8

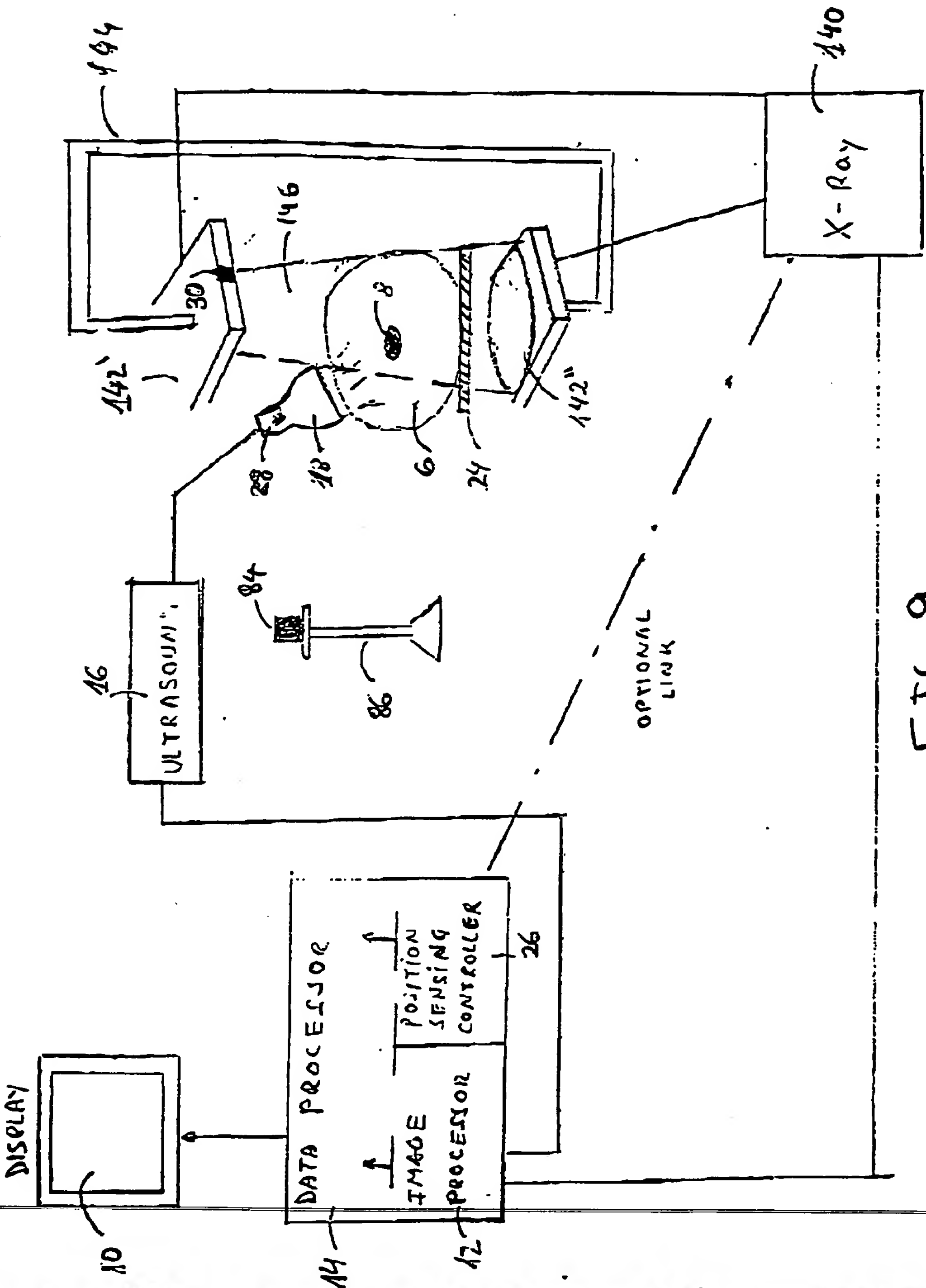
DISPLAY
10
DATA PROCESSOR
14
IMAGE PROCESSOR
12
POSITION SENSING CONTROLLER
26
ULTRASOUND
16
84
86
OPTIONAL LINK
28
18
6
24
8
30
142'
142"
146
144
X-Ray
140

FIG. 9

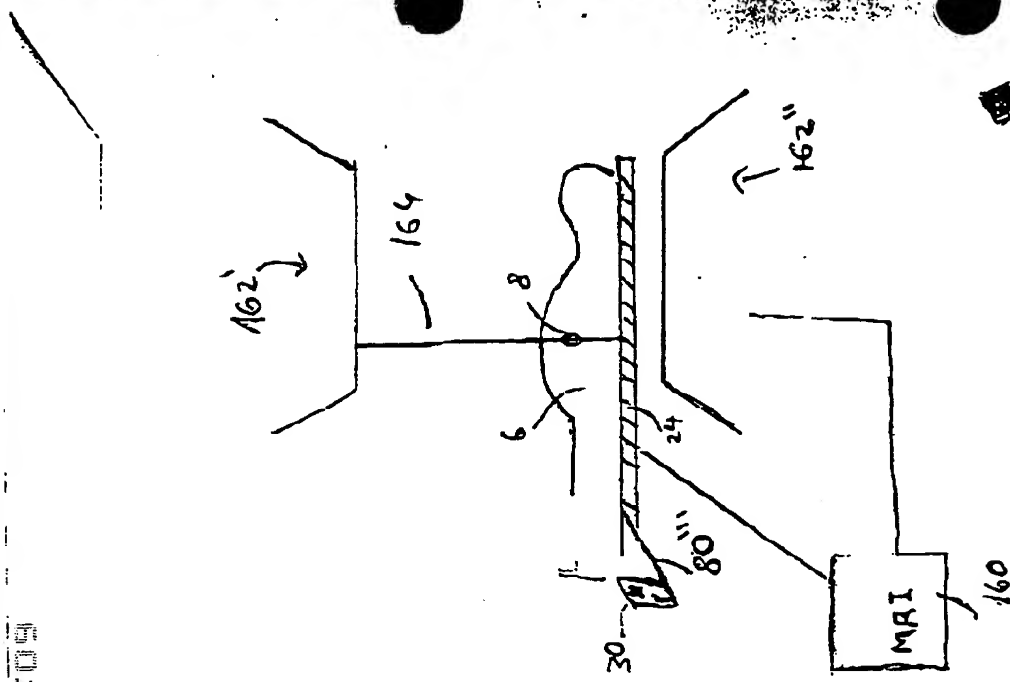

FIG. 10b

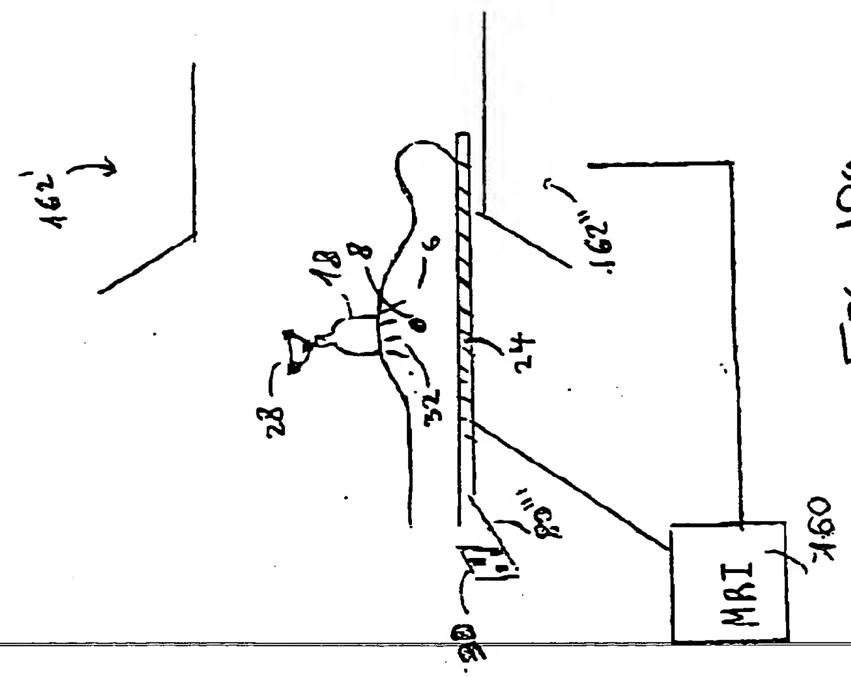

FIG. 10a

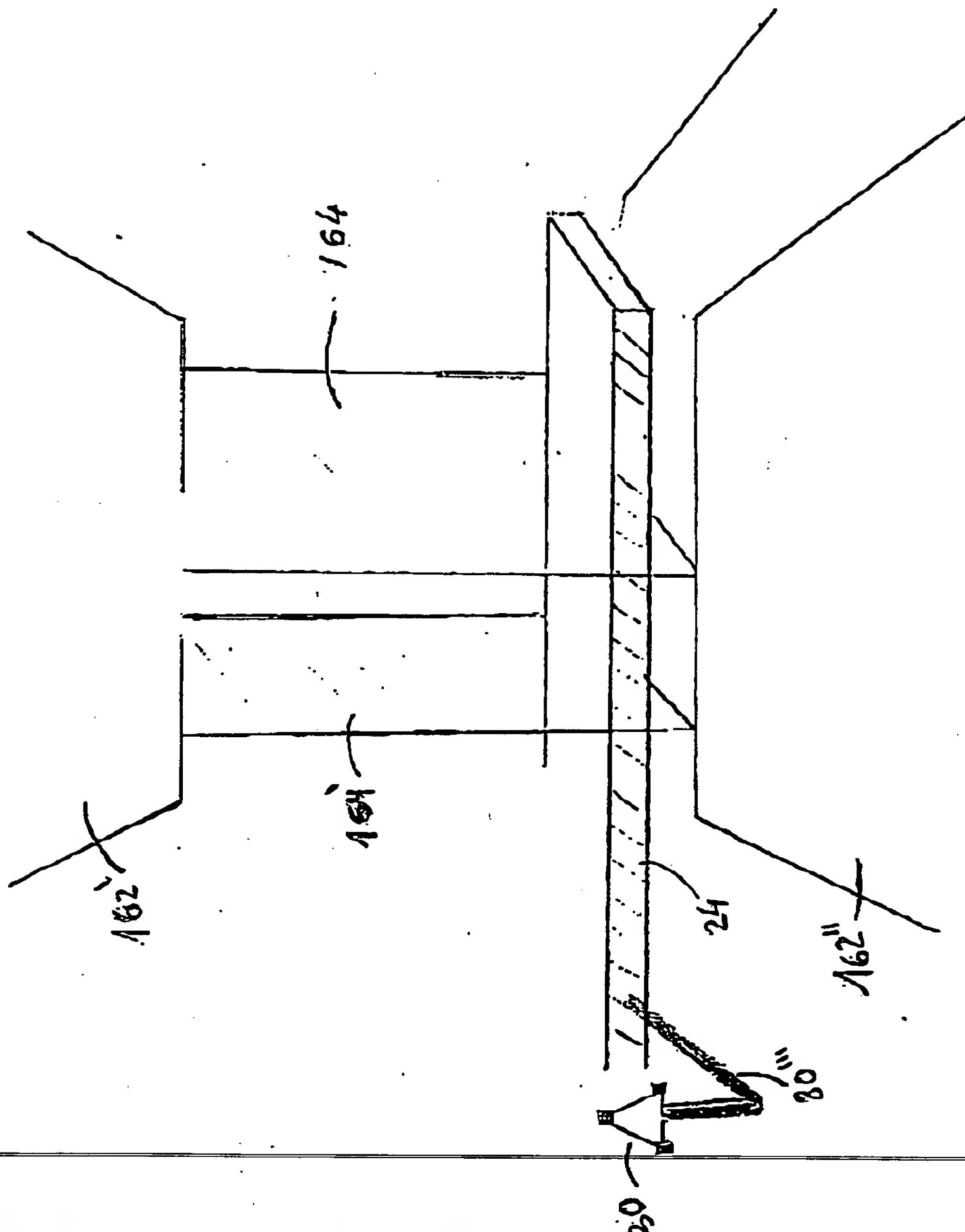

FIG. 11